PERGAMON

Computers & Industrial Engineering 38 (2000) 435–455

computers & industrial engineering

www.elsevier.com/locate/dsw

Hierarchical stochastic production planning for flexible automation workshops

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Accepted 24 August 2000

Abstract

This paper presents the hierarchical stochastic production planning (HSPP) problem for flexible automation workshops (FAWs) in agile manufacturing environments, which is a multiple-period multiple-product problem with random material supply, demands, capacities, processing times, rework and waste products. To solve the HSPP problem, a mathematical model is built up first. Then, an algorithm for HSPP is deduced in detail by using a stochastic interaction/prediction approach. The corresponding software package named as stochastic interaction/prediction algorithm (SIPA) has been developed and is presented in this paper, through which examples of HSPP have been studied, and which show that the algorithm can optimally decompose medium-term random product demand plans of an FAW into short-term stochastic production plans to be executed by FMSs in the FAW. Finally, the application of the algorithm is presented in detail through one of those examples.

Keywords: Hierarchical stochastic production planning; Flexible automation workshop; Stochastic interaction/prediction algorithm

1. Introduction

A manufacturing department of a manufacturer in China is usually composed of several workshops or sub-factories, each of which is usually composed of some workshop-sections. Thus, the manufacturing department of the computer integrated manufacturing system (CIMS) in such a manufacturer is also composed of several shops, each of which consists of some manufacturing cells or flexible manufacturing systems (FMSs). Secondly, in theory, the workpiece-transport time and charges can be decreased by reconfiguration of the manufacturing cells (Chung & Fang, 1993; Rheault, Drolet & Abdulnour, 1995).

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PII: S0360-8352(00)00056-5

However, because main machines in cells (or FMSs) are NC machines and machining centers that cannot be arbitrarily moved, the physical reconfiguration of cells cannot be realized and the logical reconfiguration of cells cannot obviously decrease the workpiece-transport time and charges. Thirdly, although the commercial software of manufacturing resource planning (MRP II) can directly assign manufacturing orders to manufacturing cells, these orders are usually not optimal (Zou & Su, 1994). This is because the manufacturing orders are made according to a material requirement plan that, without workcentre capacities being taken into consideration, is generated only from a master production schedule, bill and lead time of a material. After the manufacturing orders are obtained, a capacity requirement plan is developed by simulation. If the capacity requirement plan does not match workcentre capacities, these manufacturing orders are revised manually after the amount of material to be procured and/or the amount of work to be subcontracted have been changed manually, or other manufacturing orders are remade after the master production schedule has been modified manually until they match each other. Thus, those manufacturing orders are not optimal. It is better for MRP II to assign a shop the manufacturing orders that are to be optimally decomposed into short-term plans to be executed by manufacturing cells or FMSs in the shop, about which little has been written in the literature on production planning (PP). Fourthly, the solutions of PP problems in workshops will provide a theoretical basis for implementing manufacturing execution systems (Baliga, 1997) similar to shop floor controllers. Fifthly, with the increasingly keen competition for markets, there will be no manufacturer that has all the resources to win a victory. Thus, several manufacturers with complementary resources will temporarily form themselves into an agile virtual enterprise (Goranson, 1995) to take advantage of a transient market opportunity and to win a victory in the competition. In such an agile manufacturing environment, a shop is empowered to organize production autonomously according to manufacturing orders (product demand plans) not only from the manufacturer (which it belongs to) but also from the agile virtual enterprise (which it belongs to), which generates more uncertainty in the product demand than the traditional production. Besides, the equipment capacity in the shop is uncertain because of unplanned maintenance and the material supply for the shop is also uncertain because of the supplier's capacity and the material quality. Therefore, the shop can be taken as a stochastic manufacturing system to some extent. On the other hand, the production planning in a manufacturing setting is essential to achieve efficient resource allocation over time while meeting demands for finished products. It is thus clear that the study on the stochastic PP problem for a flexible automation workshop (FAW) consisting of FMSs (or cells) is of great significance.

Since the scope of PP problems generally prohibits a monolithic modeling approach, a hierarchical production planning (HPP) approach has been widely advocated in the PP literature (Davis & Thompson, 1993). To model PP problems, the existing hierarchical approaches usually employ the following concepts: (1) product disaggregation (Davis & Thompson, 1993; Bitran, Haaas & Hax, 1981; Graves, 1982; Simpson & Erenguc, 1998; Simpson, 1999; Kira, Kusy & Rakita, 1997), (2) temporal decomposition (Malakooti, 1989; Nguyen & Dupont, 1993; Carravilla & Sousa, 1995; Qiu & Burch 1997; Bassok & Akella, 1991), (3) process decomposition (Villa, 1989; Yan, 1997; Yan & Jiang, 1998), and (4) event-frequency decomposition (Gershwin, 1988). However, these articles focus on deterministic HPP problems except (Davis & Thompson, 1993; Gfrerer & Zapfel, 1995; Kira et al., 1997) that are on the HSPP problems.

The existent articles on the PP problems with uncertainties mostly focus on uncertainties of the demand, capacity and material supply in the single-period or infinite-horizon setting (Bassok & Akella, 1991; Ciarallo, Akella & Morton, 1994; Ishikura, 1994; Kasilingam, 1995; Metters, 1997; Hwang &